Design and Analysis of LTE MIMO Handset Antenna with Enhanced Isolation using Decoupling Technique

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1. Introduction

In the future, wireless communications require higher data rate for various mobile services. One of the most noticeable techniques for the next generation wireless communication is Long-Term Evolution (LTE) not only at 700MHz band but also at other various bands. Multiple-input-multiple-output (MIMO) system is essential for this technique. MIMO systems use multiple antennas at transmitter and receiver to enhance the performance of wireless communications: the channel capacity. However, in order to design MIMO systems for mobile handsets that have limited spaces, isolation between antennas positioned closely to each other should be considered because the poor isolation means degradation of the performance of MIMO systems. Various methods have been found to enhance isolation [1-3]. Among those three methods, decoupling technique from [2] has many advantages. The parameters composing the decoupling network can be easily calculated from measured scattering parameters, and they are also adoptable for any antenna structures.

In this paper, we have presented the comparison of the two MIMO antennas for LTE applications in 700MHz band, with and without decoupling network. For the performance evaluation of the proposed MIMO antennas, relationship between the isolation and channel capacity was investigated.

2. Antenna Design

The geometry of the proposed Inverted-F Antenna (IFA) is shown in Fig. 1. The size of FR-4 substrate ($\varepsilon_r = 4.6$) is 100 x 50 x 1 mm^3 considered as the practical smart phone. And the upper side of the substrate is connected to the bottom side through via holes. The size of the antenna is 49.5 x 7 x 6 mm^3. The measured bandwidth (S11 < -6dB) is about 100MHz from 698MHz to 798MHz in case of the single antenna. Plastic supporter is made of ABS ($\varepsilon_r = 2.8$) and protects radiator from external impacts. The proposed antenna is fed by 50 Ω coaxial cable. To achieve good input impedance matching, the matching circuit which is composed of a lumped capacitor and inductor is connected to the antenna. The values of matching components are C = 3pF and L = 2.7nH.

The proposed antenna was used to realize the MIMO antenna shown in Fig. 2(a). The radiators are located at top and bottom of the main substrate, and the distance between two antennas is 100 mm ($0.25\lambda_0$ at 750MHz). The measured scattering parameters and radiation patterns of the MIMO antenna are shown in Fig. 3 and 4. Return Loss and radiation pattern of each port are measured when another port is terminated to a 50 Ω load. The measured maximum gains are 1.592 dBi at port 1 and 1.907 dBi at port 2, and these values are observed at 758 MHz in the *y-z* plane.

3. Adoption of Decoupling Technique

In the proposed MIMO antenna, decoupling technique was used to achieve high isolation. Decoupling network is composed of two transmission lines and a shunt lumped element. The electrical length θ of transmission line and susceptance B of shunt lumped element form the decoupling network were derived in [2]. The following equations are the solutions of the parameters.

$$\theta = \frac{1}{2}(\phi \pm \frac{\pi}{2} + n\pi) \quad (1)$$

and

$$B = \pm \frac{2\alpha}{(1+\alpha^2)Z_0} \quad (2)$$

where Z_0 is characteristic impedance of the transmission line, α and ϕ are the amplitude and phase of the coupling coefficient S_{21} without decoupling network. The measured coupling coefficient is $0.288e^{-j33.5°}$ at 750MHz. From (1) and (2), θ = 118° and B = 0.532/ Z_0 (or a capacitance of 2.26pF) are obtained. In practice, to realize the decoupling network, Coplanar Waveguide (CPW) and a 2.7pF capacitor were used. In addition, matching circuit which consists of a series inductor (8.2nH) and a shunt capacitor (2pF) was also used to achieve input impedance matching. Finally, the complete configuration, measured scattering parameters, and radiation patterns of the MIMO antenna adopted decoupling technique are shown in Fig. 2(b), 5, 6 respectively. The measured maximum gains are 3.092 dBi at port 1 and 2.895 dBi at port 2, and these values are observed at 758 MHz in the *y*-*z* plane.

4. Measurement of the Channel Capacity

Relationship between the isolation and channel capacity was investigated to evaluate the performance of MIMO antennas. The channel capacity was measured in the RC. As multipath fading takes place in real communication environment, this phenomenon is repeatedly realized by rotating a mode stirrer in the RC [4]. To obtain the channel capacity, the channel matrices (**H**-matrices) should be measured. The way to measure **H**-matrices in the RC is described in [5]. The channel capacity is defined as

$$C = \log_2[\det(\mathbf{I} + \frac{\rho}{M_t}\mathbf{HH}^H)] \quad (3)$$

where **I** is the M_r x M_r identity matrix, ρ is the average signal-to-noise ratio, M_t is the number of transmitter, and *H* denotes complex conjugate. The RC where the measurement was performed has the dimension of 2.5 x 3.7 x 2.9 m^3 within a z-folded-shape mode stirrer. The resolution of the mode stirrer is set as 0.9° which means 400 measurements for each frequency. Two dipole antennas with the separation distance of 1λ were used for transmitter. Receiver was positioned in the working volume of the RC.

5. Results and Discussion

In MIMO systems, isolation is the most important parameter because isolation influences the channel capacity. Enhancement of the isolation corresponds to reduction of the mutual coupling, and this means that the efficiency of the antennas is improved and the signal leakage is reduced. As a result, the channel capacity is enhanced. The compared isolations with and without the decoupling network are shown in Fig. 7. In case of the MIMO antenna adopted decoupling technique, better isolation characteristic is achieved. And the channel capacity measured for each frequency is shown in Fig. 8. In this case, the SNR is fixed to 27dB. The channel capacity enhances in the frequency range starting from 718MHz to 768MHz.

6. Conclusion

This paper has presented the novel IFA and its MIMO application for 700MHz-LTE band. In case of MIMO antenna, to enhance isolation between two antennas, decoupling technique is adopted. As a result, the isolation and channel capacity of the MIMO antenna are increased while retaining the original radiation patterns. Also, the maximum radiation gain is enhanced.

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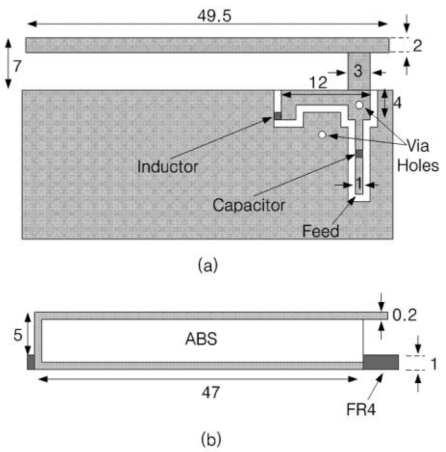

Figure 1: The geometry of the proposed IFA (a) Front view (b) Top view (Unit: mm)

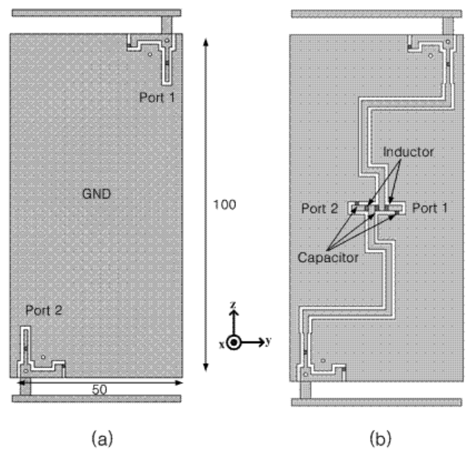

Figure 2: The proposed MIMO antenna (a) without decoupling network (b) with decoupling network

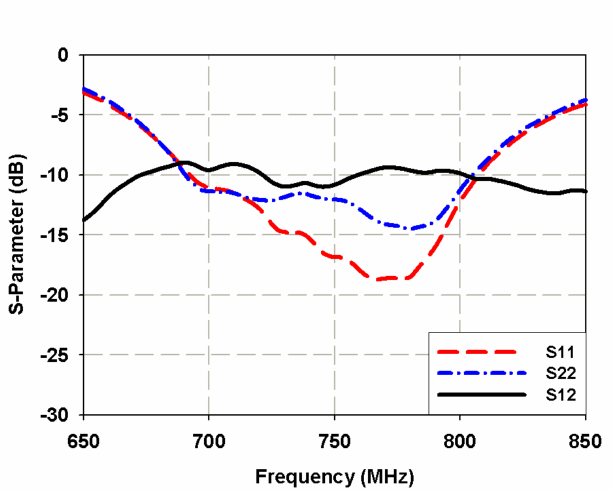

Figure 3: The measured return loss and isolation of the proposed MIMO antenna

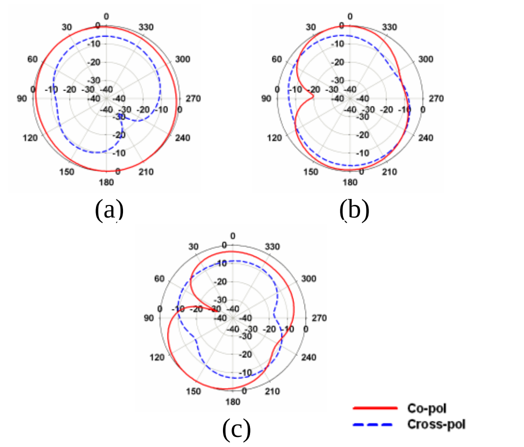

Figure 4: The measured radiation patterns of the proposed MIMO antenna at 750MHz (a) x-y plane (b) x-z plane (c) y-z plane

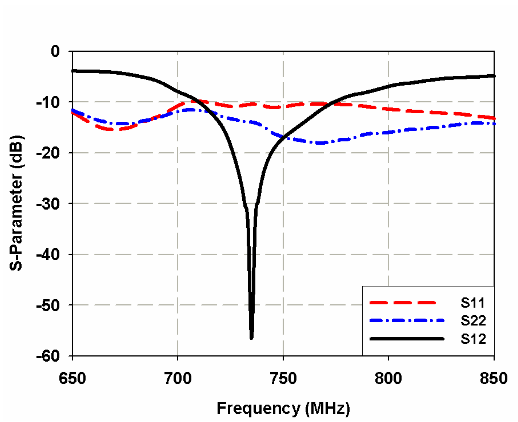

Figure 5: The measured return loss and isolation of the MIMO antenna adopted decoupling technique

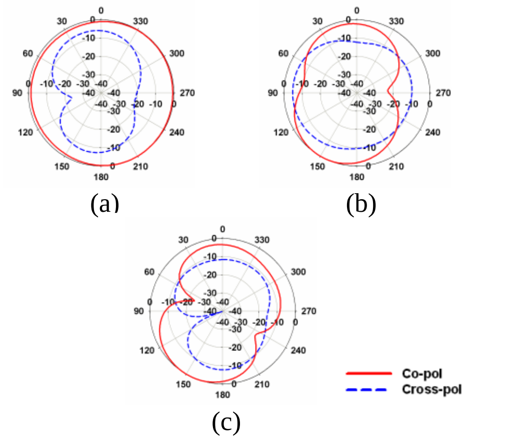

Figure 6: The measured radiation patterns of the proposed MIMO antenna adopted decoupling technique at 750MHz (a) x-y plane (b) x-z plane (c) y-z plane

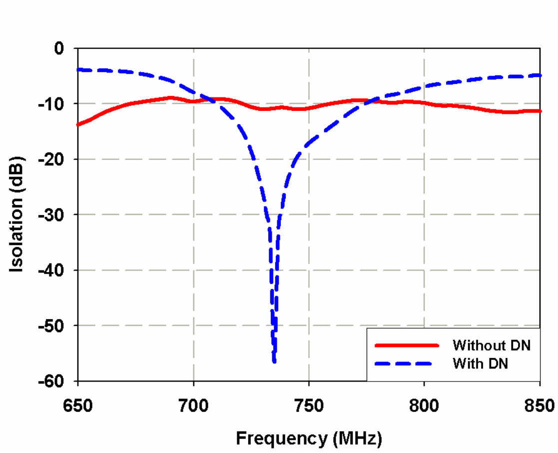

Figure 7: The isolations between two elements with and without the decoupling network

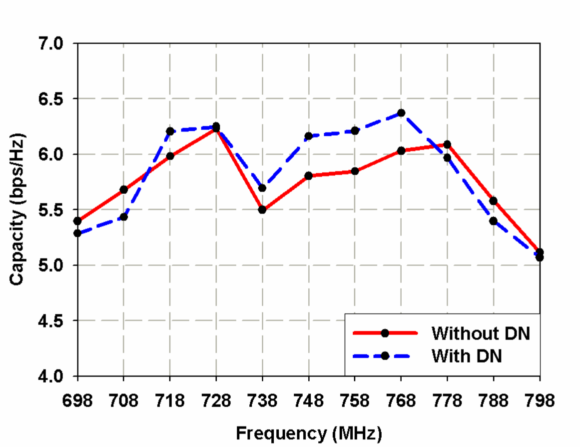

Figure 8: The measured channel capacity with and without the decoupling network in the RC when the SNR is fixed to 27dB

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